

WHAT IS CLAIMED IS:

1. An NO<sub>x</sub> measurement apparatus comprising an NO<sub>x</sub> sensor element which includes:

a flow passage to which an analyte gas is introduced;  
an oxygen partial pressure detection cell for detecting oxygen concentration of the analyte gas introduced to the flow passage;

a first oxygen pump cell for pumping oxygen out of the interior of the flow passage to the exterior of the flow passage, or for pumping oxygen into the interior of the flow passage from the exterior of the flow passage, on the basis of the oxygen concentration detected by the oxygen partial pressure detection cell, so that current corresponding to the oxygen concentration of the gas introduced to the flow passage flows through the first oxygen pump cell; and

a second oxygen pump cell to which the analyte gas having an oxygen concentration controlled by the first oxygen pump cell flows and which decomposes nitrogen oxides within the gas and causes oxygen dissociated from the nitrogen oxides to migrate, wherein

a predetermined voltage is applied across the second oxygen pump cell, and the nitrogen oxides concentration of the analyte gas is measured based on current flowing

through the second oxygen pump cell,

the NOx measurement apparatus further comprising:

voltage generation means, connected between the second oxygen pump cell and a power source, for generating, from a voltage supplied from the power source, a voltage to be applied across the second oxygen pump cell; and

clamp means, connected between the voltage generation means and the second oxygen pump cell, for clamping the voltage applied across the second oxygen pump cell to a predetermined voltage which is higher than a predetermined measurement voltage to be applied across the second oxygen pump cell during measurement but not higher than a voltage supplied from the power source.

2. An NOx measurement apparatus according to claim 1, wherein

the voltage generation means includes an amplification circuit having a power source terminal for receiving drive voltage from the power source, a non-inverted input terminal for receiving a variably set input voltage, and an inverted input terminal and an output terminal which are connected to each other; and

the clamp means includes a diode which is connected to a node between the inverted input terminal and the output

terminal and which enters a conductive state when a voltage higher than the predetermined voltage is applied across the second oxygen pump cell, to thereby limit the voltage applied across the second oxygen pump cell to the predetermined voltage or below.

3. An NOx measurement apparatus according to claim 2, wherein a circuit is connected between the inverted input terminal and the output terminal of the amplification circuit, and is adapted to change the amplification ratio of the amplification circuit, when the NOx sensor element or the second oxygen pump cell is activated, in order to generate a voltage higher than the voltage applied across the second oxygen pump cell during ordinary measurement.

4. An NOx measurement apparatus according to claim 3, wherein immediately after the predetermined voltage is applied across the second oxygen pump cell when the NOx sensor element or the second oxygen pump cell is activated, the input voltage is changed in such a manner that a voltage close to and greater than the measurement voltage is applied across the second oxygen pump cell.

5. An NOx measurement apparatus according to claim

1, wherein

the NOx measurement apparatus measures nitrogen oxides concentration of exhaust gas discharged from an internal combustion engine mounted on a vehicle; and

the power source is a battery power source for driving or controlling the internal combustion engine.

6. An NOx measurement apparatus according to claim 1, wherein

the flow passage is formed by a first diffusion resistance, a first measurement chamber to which the analyte gas is introduced via the first diffusion resistance; a second diffusion resistance, and a second measurement chamber to which the gas is introduced via the second diffusion resistance from the first measurement chamber;

the NOx sensor element includes an oxygen partial pressure detection cell having two electrodes provided at the interior and exterior, respectively, of the first measurement chamber and adapted to detect oxygen concentration of the analyte gas within the first measurement chamber based on a potential difference between the electrodes of the oxygen partial pressure detection cell; a first oxygen pump cell having two electrodes

provided at the interior and exterior, respectively, of the first measurement chamber and adapted to pump oxygen out of the interior of the first measurement chamber to the exterior of the first measurement chamber, or pump oxygen into the interior of the first measurement chamber from the exterior of the first measurement chamber, through the electrodes of the first oxygen pump cell, whereby a current (hereinafter referred to as "first oxygen pump current") corresponding to oxygen concentration of the analyte gas flows between the electrodes of the first oxygen pump cell; a second measurement chamber to which the analyte gas is introduced from the first measurement chamber via the second diffusion resistance; and a second oxygen pump cell having two electrodes provided at the interior and exterior, respectively, of the second measurement chamber and adapted to decompose nitrogen oxides within the second measurement chamber and cause oxygen dissociated from the nitrogen oxides to migrate, whereby a current (hereinafter referred to as "second oxygen pump current") corresponding to NO<sub>x</sub> concentration of the analyte gas flows between the electrodes of the second oxygen pump cell; and

the NO<sub>x</sub> measurement apparatus further comprises;

oxygen-partial-pressure-detection-cell control means for controlling oxygen concentration on the external-side

electrode of the oxygen partial pressure detection cell;

first-oxygen-pump-cell control means for controlling the first oxygen pump current by applying a predetermined voltage to the first oxygen pump cell based on a detection signal output from the oxygen partial pressure detection cell to thereby control the oxygen concentration within the first measurement chamber;

second-oxygen-pump-cell control means for applying a predetermined voltage to the second oxygen pump cell in order to control the second oxygen pump cell in such a manner that second oxygen pump current corresponding to the NO<sub>x</sub> concentration flows through the second oxygen pump cell;

activation means for applying a high voltage to the second oxygen pump cell when the second oxygen pump cell is to be activated, the high voltage being higher than the measurement voltage to be applied across the second oxygen pump cell during ordinary measurement;

second-oxygen-pump-current detection means for detecting the second oxygen pump current; and

clamp means, connected between the second oxygen pump cell, and the second-oxygen-pump-cell control means and the activation means, for clamping and limiting the voltage applied across the second oxygen pump cell to the

predetermined voltage or less which is to be applied across the second oxygen pump cell during activation.

7. An NOx measurement apparatus according to claim 6, wherein

the second-oxygen-pump-current detection means includes a detection resistance through which the second oxygen pump-current flows;

the second-oxygen-pump-cell control means includes an operational amplifier for controlling the voltage applied across the second oxygen pump cell to a predetermined value; and

the clamp means includes a diode connected to a node between the detection resistance and the output terminal of the operational amplifier.

8. An NOx measurement apparatus which comprises an NOx sensor element which includes:

an oxygen-ion-conductive solid electrolyte,

a flow passage which is disposed within or adjacent to said solid electrolyte and to which an analyte gas is introduced;

an oxygen partial pressure detection cell for detecting oxygen partial pressure of the analyte gas

introduced to the flow passage;

a first oxygen pump cell for controlling the oxygen partial pressure of said analyte gas introduced to the flow passage by pumping oxygen out of the interior of the flow passage to the exterior of the flow passage, or by pumping oxygen into the interior of the flow passage from the exterior of the flow passage based on the oxygen partial pressure detected by the oxygen partial pressure detection cell; and

a nitrogen oxides detection cell which causes dissociated oxygen resulting from decomposition of nitrogen oxides in the gas controlled for the oxygen partial pressure to migrate within said solid electrolyte, wherein

a predetermined voltage is applied across said nitrogen oxides detection cell, and the nitrogen oxides concentration of the analyte gas is measured based on a current flowing through said solid electrolyte,

said NO<sub>x</sub> measurement apparatus being characterized by comprising:

voltage generation means, connected between said nitrogen oxides detection cell and a power source, for generating, from a voltage supplied from the power source, a voltage to be applied across said nitrogen oxides



detection cell; and

clamp means, connected between the voltage generation means, for generating a voltage to be applied across said nitrogen oxides detection cell, and said nitrogen oxides detection cell, for always preventing an overvoltage applied across said nitrogen oxides detection cell and allowing a voltage which is sufficiently higher than a measurement voltage to be applied across said nitrogen oxides detection cell during activation of said NOx sensor element.

9. An NOx measurement apparatus as claimed in claim 1, wherein said predetermined voltage applied across the second oxygen pump cell is about 400 to about 550 mV.

10. An NOx measurement apparatus as claimed in claim 1, wherein said clamp means comprises a diode and two resistances, a terminal of the diode being connected to the two resistances.